a second stage for supporting a mask on which a predetermined pattern is formed;

an illumination optical system for emitting exposure light of a predetermined wavelength and transferring the pattern of the mask onto the substrate; and

a catadioptric reduction projection optical system provided between said first stage and said second stage, for projecting a reduced image of the pattern of the mask onto the substrate, said catadioptric reduction projection optical system including:

a first imaging optical system having a positive refractive power and for forming a first intermediate image as a reduced image of the pattern on the mask;

beam splitting means for splitting at least part of a light beam from said first imaging optical system;

a second imaging optical system including a concave reflecting mirror for reflecting a light beam split by said beam splitting means, and for forming a second intermediate image as an image of the first intermediate image; and

a third imaging optical system for forming a third intermediate image as an image of the second intermediate image on the substrate on the basis of a light beam, of a light beam from said second imaging optical system, which is split by said beam splitting means.

9. An apparatus according to claim 8, wherein said beam splitting means is a prism type beam splitter, and at least one of the first intermediate image and the second intermediate image is formed in said prism type beam splitter.

10. An apparatus according to claim 9, wherein an optical axis of said first imaging optical system corresponds to an optical axis of said second imaging optical system, and said beam splitting means is disposed between said first imaging optical system and said second imaging optical system.

11. An apparatus according to claim 9, wherein an optical axis of said second imaging optical system corresponds to an optical axis of said third imaging optical system, and said beam splitting means is disposed between said second imaging optical system and said third imaging optical system.

12. An apparatus according to claim 8, wherein said beam splitting means is a partial reflecting mirror for partially reflecting a light beam, and the second intermediate image is formed between said beam splitting means and said concave reflecting mirror of said second imaging optical system.

13. An apparatus according to claim 12, wherein said partial reflecting mirror is disposed so as to avoid optical axes of said first and third imaging optical systems.

14. An apparatus according to claim 8, wherein the following conditions are satisfied:

$$p_1+p_3>0,\ p_2<0,$$

and

$$|p_1+p_2+p_3|<0.1$$

where p_1 is the Petzval sum of said first imaging optical system, p_2 is the Petzval sum of said second imaging optical system, and p_3 is the Petzval sum of said third imaging optical system, and the following conditions are satisfied:

$$0.1\leq|\beta_1|\leq 1,$$

$$0.5\leq|\beta_2|\leq 2,$$

$$0.25\leq|\beta_3|\leq 1.5, \text{ and}$$

$$|\beta_1\cdot\beta_2\cdot\beta_3|<1$$

where β_1 is the magnification between the pattern of the first surface and the first intermediate image, β_2 is the magnification between the first intermediate image and the second intermediate image, and β_3 is the magnification between the second intermediate image and the third intermediate image.

* * * * *

15. A catadioptric imaging optical system in a projection exposure apparatus in which a pattern on a reticle placed on a first surface is transmitted onto a substrate placed on a second surface, comprising:

a first dioptric imaging optical sub-system;

a catadioptric imaging optical sub-system in an optical path between said first dioptric imaging optical sub-system and the second surface, comprising a concave mirror and a catadioptric optical axis; and

a second dioptric imaging optical sub-system in an optical path between said catadioptric imaging optical sub-system and the second surface, comprising a second dioptric optical axis,

wherein

a primary image is formed between said first dioptric imaging optical sub-system and said catadioptric imaging optical sub-system,

a secondary image is formed between said catadioptric imaging optical sub-system and said second dioptric imaging optical sub-system, and

the catadioptric optical axis intersects the second dioptric optical axis.

16. The optical system according to claim 15, wherein said catadioptric imaging optical sub-system further comprises a negative power lens.

17. The optical system according to claim 15, further comprising a turning mirror located off the second dioptric optical axis.

18. The optical system according to claim 17, wherein the secondary image is formed between said turning mirror and the concave mirror.

19. The optical system according to claim 15, further comprising an aperture stop in said first and/or second dioptric optical sub-system, which controls a coherent factor.

20. The optical system according to claim 15, wherein the second dioptric optical axis is along a straight line.

21. The optical system according to claim 20, wherein said first dioptric imaging optical sub-system comprises a first dioptric optical axis along a straight line.

22. A projection exposure apparatus which transfers a pattern on a reticle onto a substrate, comprising:

a catadioptric imaging optical system according to claim 15, wherein said catadioptric imaging optical system forms an exposure area at a position off the second dioptric optical axis.

23. The projection exposure apparatus according to claim 22, wherein the reticle and the substrate are scanned at different speeds corresponding to a magnification of said catadioptric imaging optical system.

24. A method of imaging a pattern on a reticle onto a substrate, comprising:

passing a light from the reticle through a first dioptric imaging optical sub-system;

passing a light from the first dioptric imaging optical sub-system through a catadioptric imaging optical subsystem having a concave mirror;

passing a light from the catadioptric optical sub-system through a second dioptric imaging optical sub-system;

forming a primary image between the first dioptric imaging optical sub-system and the catadioptric imaging optical system;

forming a secondary image between the catadioptric imaging optical system and the second dioptric imaging optical sub-system; and

turning an optical path near the primary image.

25. A method of imaging a pattern on a reticle onto a substrate, comprising:

passing a light from the reticle through a first dioptric imaging optical sub-system;

passing a light from the first dioptric imaging optical sub-system through a catadioptric imaging optical subsystem having a concave mirror;

passing a light from the catadioptric optical sub-system through a second dioptric imaging optical sub-system;

forming a primary image between the first dioptric imaging optical sub-system and the catadioptric imaging optical system;

forming a secondary image between the catadioptric imaging optical system and the second dioptric imaging optical sub-system; and

turning an optical path near the secondary image.

26. The method according to claim 25, wherein the optical path is turned by a turning mirror located off an optical axis of the second dioptric imaging optical sub-system.

27. The method according to claim 25, further comprising controlling a coherent factor using an aperture stop in the first and/or second dioptric imaging optical sub-system.

28. The method according to claim 27, further comprising arranging the reticle and the substrate to be parallel.

29. The method according to claim 28, further comprising turning an optical path in the first dioptric imaging optical sub-system.

30. A catadioptric imaging optical system in a projection exposure apparatus in which a pattern on a reticle placed on a first surface is transferred onto a substrate placed on a second surface, comprising:

a first dioptric imaging optical sub-system;

a catadioptric imaging optical sub-system in an optical path between said first dioptric imaging optical sub-system and the second surface, comprising a concave mirror;

a second dioptric imaging optical sub-system in an optical path between said catadioptric imaging optical sub-system and the second surface; and

a turning mirror between said catadioptric imaging optical system and said second dioptric imaging optical sub-system,

wherein

a primary image is formed between said first dioptric imaging optical sub-system and said catadioptric imaging optical sub-system, and

a secondary image is formed between said catadioptric imaging optical sub-system and said second dioptric imaging optical sub-system.

31. The optical system according to claim 30, wherein the secondary image is formed between said turning mirror and the concave mirror.

32. The optical system according to claim 30, further comprising an aperture stop in said first and/or second dioptric optical sub-system, which controls a coherent factor.

33. The optical system according to claim 30, wherein said second dioptric imaging optical sub-system has an optical axis along a straight line.

34. The optical system according to claim 33, wherein said first dioptric imaging optical sub-system has an optical axis along a straight line.

35. A projection exposure apparatus which transfers a pattern on a reticle onto a substrate, comprising:

a catadioptric imaging optical system according to claim 30, wherein said catadioptric imaging optical system forms an exposure area off an optical axis of said second dioptric imaging optical sub-system.

36. The projection exposure apparatus according to claim 35, wherein the reticle and the substrate are scanned at different speeds corresponding to a magnification of said catadioptric imaging optical system.

37. A method of imaging a pattern on a reticle onto a substrate, comprising:

forming a primary image of the reticle by a first dioptric imaging optical sub-system, based on light from the reticle;

forming a secondary image of the reticle using a catadioptric imaging optical sub-system having a concave mirror, based on light from the first dioptric imaging optical sub-system;

forming a final image of the reticle on the substrate using a second dioptric imaging optical sub-system, based on light from the catadioptric imaging optical system; and

turning an optical path between the catadioptric imaging optical system and the second dioptric imaging optical sub-system.

38. A catadioptric imaging optical system in a projection exposure apparatus in which a pattern on a reticle placed on a first surface is transferred onto a substrate placed on a second surface, comprising:

a first dioptric imaging optical sub-system comprising an optical axis along a straight line;

a catadioptric imaging optical sub-system in an optical path between said first dioptric imaging optical sub-system and the second surface, comprising a concave mirror and an optical axis along a straight line; and

a second dioptric imaging optical sub-system in an optical path between said catadioptric imaging optical sub-system and the second surface, comprising an optical axis along a straight line.

39. The optical system according to claim 15, wherein said first dioptric imaging optical sub-system, said catadioptric imaging optical sub-system, and said second dioptric imaging optical sub-system further comprise lenses having the same material.

40. The optical system according to claim 15, wherein the optical system satisfies the following conditions:

$0.1 \le |\beta_1| \le 1$,

$0.5 \le |\beta_2| \le 2$,

$0.25 \le |\beta_3| \le 1.5$, and

$|\beta_1 \cdot \beta_2 \cdot \beta_3| \le 1$,

wherein β_1 is a magnification for said first dioptric imaging optical sub-system, β_2 is a magnification for said catadioptric imaging optical sub-system, and β_3 is a magnification for said second dioptric imaging sub-system

41. The optical system according to claim 15, further comprising a turning mirror, and wherein the first surface is parallel to the second surface.

42. The optical system according to claim 41, wherein said tuning mirror is in said first dioptric imaging sub-system.

43. A method of imaging a pattern on a reticle onto a substrate, comprising:

forming a primary image of the pattern using a first dioptric imaging optical sub-system comprising a first dioptric optical axis along a straight line;

forming a secondary image of the pattern using a catadioptric imaging optical sub-system comprising a concave mirror and a catadioptric optical axis along a straight line, the second image being formed using light received from the first dioptric imaging optical sub-system; and

forming a final image of the pattern on the substrate using a second dioptric imaging optical sub-system comprising a second dioptric optical axis along a straight line, the final image being formed using light received from the catadioptric imaging optical sub-system.

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Continuation Application Transmittal form; Fee Transmittal Form; Specification (13 pgs), drawings (FIGs. 1 - 15, 16A, 16B, and 16C- 28), Preliminary Amendment (26 pages); Consent of Assignee (2 pages); Reissue Application Declaration (4 pages); information Disclosure Statement; PTO Form 1449 (4 pages); Attachment 1(f); Attachment 1 (g); Cheque for $4720.00

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